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A REMOTE TYRE PRESSURE MONITORING SYSTEM

Field of the Invention

The present invention relates to a system for monitoring the pressure of ~~tyres~~ tires in a wheeled vehicle. In particular, the invention relates to a ~~tyre~~ tire pressure monitoring system employing individual battery-powered pressure sensors associated with each ~~tyre~~ tire for transmitting coded information to a receiver mounted within the vehicle to provide information about the condition of the ~~tyres~~ tires to a driver of the vehicle.

Background to the Invention

It is well known that for commercial vehicles even a small deviation from the correct ~~tyre~~ tire pressure can adversely affect ~~tyre~~ tire wear and substantially increase the fuel consumption of the vehicle. Constant under inflation can reduce a ~~tyre's~~ tire's life by up to 50%. A worn commercial ~~tyre~~ tire which is in every other sense in good condition can usually be retreaded twice. However, once the ~~tyre~~ tire walls are damaged through under inflation this is not possible. Furthermore, the majority of "blow-outs", ~~tyre~~ tire shredding and vehicle fires are caused by ~~tyre~~ tire under inflation. As a result, many large vehicle fleet operators spend significant sums on checking ~~tyre~~ tire pressures regularly. Most of this would be rendered unnecessary by a reliable automatic pressure monitoring system.

Summary of the Invention

According to a first aspect of the present invention, a battery-powered ~~tyre~~ tire pressure sensor comprises:

INS A1 a pressure transducer for sensing a pressure ~~of a tyre and providing a tyre~~ A pressure signal;

a transmitter:

a signal processor connected to the pressure transducer for providing a signal dependent on the ~~tyre~~ tire pressure signal to the transmitter:

a timing circuit connected to the signal processor which is configured to automatically switch ~~the tyre pressure sensor~~ the tire pressure sensor on periodically for a predetermined interval ~~to measure the tyre~~ to measure the tire pressure and switch off the ~~tyre~~ tire pressure sensor at all other times to conserve battery power, in which the timing circuit comprises a timer and a switch, the timer being configured to periodically actuate the switch and thereby connect the pressure sensor to the battery to turn the ~~tyre~~ tire pressure sensor on for said predetermined interval.

The ~~tyre~~ tire pressure sensor of the present invention is suitable for all types of vehicles, but is especially suited for fitting to commercial vehicles such as buses, coaches, trucks, and lorries. The pressure sensor monitors the pressure of a ~~tyre~~ tire and gives the vehicle driver early warning of any deflation, thereby improving safety, as well as reducing ~~tyre~~ tire wear and improving fuel economy. An important aspect of the present invention is that the pressure sensor is only switched on periodically under the control of a timer to sample the ~~tyre~~ tire pressure. This feature allows battery power to be conserved and therefore effectively extend the life of the battery or otherwise allow a smaller battery to be used.

Preferably, the pressure sensor further comprises a non-volatile memory device for storing an identification code used to identify transmissions from the pressure sensor. Preferably, the non-volatile memory device also stores calibration information which is used to determine an accurate ~~tyre~~ tire pressure. In particular, during manufacture each pressure sensor may be tested at atmospheric pressure, maximum rated pressure, and at several points

between. and the results of the calibration routine stored in the non-volatile memory device as variables which characterize the response of the pressure sensor. The advantage of a non-volatile memory is that data is not lost when the pressure sensor is switched off in the interval between pressure measurements.

Preferably. the sensor unit further comprises a temperature transducer connected to the signal processor to provide a temperature signal to the signal processor. wherein the signal processor is adapted to apply a temperature compensation to the ~~tyre~~ tire pressure signal in dependence on the temperature signal. This feature allows the signal processor to correct the output of the pressure transducer to ensure accuracy over a range of. for example. -40°C to +60°C. In addition. if the air temperature falls below say 3°C. this information can be transmitted by the pressure sensor to warn the vehicle driver that road conditions may be hazardous.

Preferably. the signal processor is a microcontroller having an embedded computer program for controlling the operation of the pressure sensor. Preferably, the microcontroller is configured to record battery voltage and operating temperature each time it makes a pressure measurement and. when necessary, encode this information together with the pressure sensor identification code for transmission via the transmitter.

Preferably. the transmitter. comprises a surface acoustic wave (SAW) resonator. Suitable radio frequencies for use in the United Kingdom include 418 MHz and 433 MHz in accordance with the radio specifications for MPT 1340 of the Radio Communications Agency. These frequencies are currently licence exempt.

In a preferred example of the present invention, the pressure sensor is adapted to be screwed onto the valve stem of a vehicle ~~tyre~~ tire. This allows the pressure sensor to be retro-fitted to existing vehicles. As an alternative, the pressure sensor may be adapted for mounting within a vehicle ~~tyre~~ tire.

Preferably, the pressure sensor is configured so that it does not make any transmissions until it is connected to an inflated ~~tyre~~ tire. This feature ensures that battery power is conserved during transport and storage of the pressure sensor before fitting to a ~~tyre~~ tire.

According to a second aspect of the present invention, a remote ~~tyre~~ tire pressure monitoring system for mounting on a vehicle comprises a plurality of ~~tyre~~ tire pressure sensors according to the first aspect of the present invention in combination with a cab unit for mounting within the vehicle cab, the cab unit comprising:

a receiver for detecting transmissions from the respective transmitters of the ~~tyre~~ tire pressure sensors; and,

a display for providing a driver with information about the ~~tyres~~ tires on the vehicles in dependence on the received transmissions from the pressure sensors.

According to a third aspect of the present invention, a transponder unit for use in a remote ~~tyre pressure~~ tire pressure monitoring system for a vehicle which includes a plurality of ~~remote tyre~~ remote tire pressure sensors connected to respective ~~tyres~~ tires, wherein each pressure sensor is adapted to transmit a signal with information about the condition of its respective ~~tyre~~ tire, the transponder unit comprising:

a receiver for receiving the transmitted signals from the individual pressure sensors;

a signal processor for processing signals from the pressure sensors and generating a coded signal for transmission which identifies the transponder unit and tire ~~tyre~~ location: and.

a transmitter for transmitting the coded signal to a remote receiver where information can be displayed to a driver about the tires ~~tyres~~ associated with the transponder unit.

The transponder unit of the present invention allows a cab unit within a vehicle cab to distinguish between transmissions from the remote tire ~~tyre~~ pressure sensors of a trailer and other pressure sensors without requiring the driver to individually register each pressure sensor of the trailer whenever the vehicle cab and trailer are first connected. This is useful since a lorry driver may change trailer frequently. The cab unit within the vehicle cab is able to "learn" the unique identifier for the trailer transponder unit so that it can recognise subsequent transmissions forwarded by the transponder unit which encode information from the tire ~~tyre~~ pressure sensors connected to the trailer tires ~~tyres~~.

According to a fourth aspect of the present invention. a remote tire ~~tyre~~ pressure monitoring system comprises a transponder unit according to the third aspect of the present invention in combination with a cab unit. wherein the cab unit comprises:

a receiver for receiving the coded signal from the transponder unit:

a signal processor for detecting and decoding the coded signal: and.

a display for providing the driver with information about the condition of the tires ~~tyres~~ associated with the transponder unit.

Preferably. the remote tire ~~tyre~~ pressure monitoring system comprises a vehicle trailer on which the transponder unit is mounted.

Preferably, the remote tire ~~remote tyre~~ pressure sensors are tire ~~tyre~~ pressure sensors in accordance with the first aspect of the present invention.

The present invention combines simplicity of operation with the most advanced solid-state electronic design. It is proposed that the valve dust cap for each wheel of a vehicle is replaced by a pressure sensor in accordance with the present invention which monitors the tire ~~tyre~~ pressure and reports to a computer controlled unit in the vehicle cab. Should, for example, the pressure in any tire ~~tyre~~ drop by more than say 12.5%, a radio signal is then sent to a display in the cab to warn the driver as to which of his tires ~~tyres~~ is losing air. The driver then has time to act before the tire ~~the tyre~~ is damaged, thereby saving on tire ~~on tyre~~ wear and fuel, and perhaps avoiding the expensive results of complete tire ~~tyre~~ failure. It is also intended that the driver should be warned if any pressure sensor is suffering from low battery power or is missing or malfunctioning in any other way. Furthermore, if the air temperature at road level approaches freezing point the system warns of possible road icing. For articulated rigs, a radio transponder unit mounted on the front of the trailer relays messages from pressure sensors connected to the trailers wheels to the vehicle cab. With aerials and cabling supplied, the system of the present invention is as easy to fit as a car radio. In addition, there is nothing to connect or disconnect when changing trailer. The cab unit is pre-programmed to accept the new set of trailer wheels but will not respond to pressure sensors from other rigs.

An important aspect of the present invention is that the pressure sensors have a long life, typically up to three years. This is achieved by the use of the timing circuit which ensures that the pressure sensor is switched off most of the time. Typically, each pressure sensor

will draw a current of significantly less than 1 μA between pressure measurements. and draw only a small current of the order of 4.5 mA when switched on.

The present invention will lead to significant savings in running costs for commercial vehicle operators; savings within the first year which should represent four times the purchase price. Added to this are the safety advantages. greater reliability. and reduced levels of tire ~~tyre~~ maintenance.

Brief Description of the Drawings

Examples of the present invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 is a block diagram of a tyre pressure monitoring system according to the present invention:

Figure 2 is a block diagram of an example of a tire ~~a tyre~~ pressure sensor for use in the tire ~~the tyre~~ pressure monitoring system of Figure 1:

Figures 3 shows a circuit implementing a temperature transducer. a pressure transducer and a reference voltage generator for use in the tire ~~tyre~~ pressure sensor of Figure 2:

Figure 4 shows a timing circuit implementing a timer and switch for use in the tire ~~tyre~~ pressure sensor of Figure 2;

Figure 5 shows an example of a transmitter and antenna circuit for use in the tire ~~tyre~~ pressure sensor of Figure 2:

Figure 6 shows an example of a non-volatile memory device for use in the tire ~~tyre~~ pressure sensor of Figure 2:

Figure 7 shows an example of a microcontroller for use in the tire ~~tyre~~ pressure sensor of Figure

2:

Figure 8 is a flow chart showing the sequence of operations for a calibration routine:

Figure 9 is a flow chart showing the sequence of operations for a ~~tyre~~ tire pressure measurement routine:

Figures 10 and 11 show a cab unit for use in the ~~tyre~~ tire pressure monitoring system of Figure 1: and.

Figure 12 is a block diagram of a transponder unit for use in the ~~tyre~~ tire pressure monitoring system of Figure 1.

Detailed Description

Figure 1 shows an example of a ~~tyre~~ tire pressure monitoring system according to the present invention. The system is suitable for mounting on the ~~tyres~~ tires of a vehicle such as a truck. bus. or coach. and also on lorries which have a vehicle cab (tractor) and a separate trailer. As shown. the system includes a cab unit 1 and a first set of ~~tyre~~ tire pressure sensor units 2_1 to 2_4. When applicable. the system includes a trailer transponder unit 3 and a second set of ~~tyre~~ tire pressure sensor units 4_1 to 4_3 associated with a trailer.

As will be described below. each of the sensor units 2_1 to 2_2 and 4_1 to 4_3 has a radio transmitter for transmitting a coded signal which carries information relating to the condition of a respective ~~tyre~~ tire to a receiver in the cab unit 1. The information is used to inform the vehicle driver about the pressure and temperature of each of the ~~tyres~~ tires by way of an audio/-visual display forming part of the cab unit 1. The transponder unit 3 is designed to be mounted on a lorry trailer and it detects transmitted signals from each of the second set of sensor units 4_1 to 4_3 associated with respective ~~tyres~~ tires of the trailer. The transponder

unit 3 transmits a coded signal to the cab unit 1 containing information about each of the trailer tires ~~tyres~~. The cab unit 1 is adapted to decode the transponder signal and distinguish between the transponder signal and any other signal so that the driver can be alerted of any fault that has occurred in relation to any of the tires ~~tyres~~ on the lorry trailer as well as the cab.

Figure 2 shows a schematic representation of an example of a battery-powered tire ~~tyre~~ pressure sensor in accordance with the present invention. The pressure sensor comprises a pressure transducer 10, a temperature transducer 11, a reference voltage generator 12, a transmitter 13 and a non-volatile memory device 14, all connected to a microcontroller 15. The device also houses a battery 16 as the power supply. The pressure sensor is periodically activated by a timing circuit 17. The timing circuit 17 comprises a switch 18 and a timer 19. The timer 19 is configured to cause the pressure sensor to sample periodically the pressure of the tire ~~tyre~~ to which the device is connected, but otherwise disconnect the other elements of the pressure sensor from the battery 16 at all other times to conserve battery power. Finally, a calibration switch 20 is provided to calibrate the pressure sensor before shipping, as will be described below. The pressure sensor is implemented on a printed circuit board and, together with the battery, sealed with a housing adapted to be screwed onto a tire ~~tyre~~ valve stem.

The pressure transducer 10 is arranged to measure the pressure of the tire ~~tyre~~ and provide an output (PRESSURE) to the microcontroller 15. A suitable device is a piezo-resistive sensor, the resistivity of which changes with changes in pressure. An example of a suitable circuit which implements a pressure transducer is shown in Figure 3.

The temperature transducer 11 is configured to measure the temperature of the air surrounding the sensor and provide an output (TEMP) to the microcontroller 15. This output signal is used to provide a temperature compensation to the pressure signal output from the pressure transducer 10 so that an accurate pressure reading can be derived for comparison with a reference value stored in the non-volatile memory device 14 (which is obtained when the pressure sensor is first connected to a ~~tyre — the tyre~~ tire — the tire having been previously correctly inflated). The temperature signal may also be used to provide a driver of the vehicle with information about related driving conditions. An example of a suitable circuit which implements a temperature sensor is shown in Figure 3.

The reference voltage generator 12 is configured to generate a stable reference voltage signal (VREF) which is provided as an input to the microcontroller 15. The microcontroller 15 compares the reference voltage with the battery voltage (VOLTS) and generates an output signal dependent on this comparison. If the battery voltage is less than the reference voltage this means that a new battery is required and a signal is generated to convey this to the driver. Furthermore, in this event, the frequency of the sampling of the ~~tyre~~ tire pressure may automatically be reduced to prolong the life of the battery until a new pressure sensor or battery can be fitted. An example of a suitable circuit which implements a reference voltage generator is shown in Figure 3.

As described above, the timing circuit 16 comprises a switch 18 and a timer 19. The timer 19 runs all the time and periodically engages the switch 18 to start a pressure measurement cycle. At all other times the remaining components of the pressure sensor are switched off to conserve battery power. Furthermore, as described above, the frequency at which the

pressure sensor is switched on is dependent on the battery voltage. When this starts to fall. the microcontroller 15 generates a warning message in the next routine status transmission and at the same time reduces the sensor sampling frequency to conserve the remaining battery life. An example of a suitable circuit which implements the timer and switch functions is shown in Figure 4. The battery 16 is a lithium device having a diameter of 16mm with a rating of typically 60-70 mAh.

The function of the radio transmitter 14 is to send messages from each ~~tyre~~ tire pressure sensor to a receiver in either the cab unit 1 of the vehicle cab or in the transponder unit 3 of a trailer. For the United Kingdom. it is proposed that the transmitter 14 transmits the signal generated by the microprocessor 15 at a frequency of either 418 MHz or 433 MHz in accordance with the MPT1 340 specification. These frequencies are currently licence exempt. A suitable type of transmitter 15 is based on a surface acoustic wave (SAW) device. An example of a suitable circuit can be seen in Figure 5.

The non-volatile memory 15 stores information about the ~~tyre~~ tire and also contains a unique pressure sensor identification code. programmed during manufacture as part of a calibration process. as will be described below. One advantage of having a non-volatile memory device 15 in the pressure sensor is that when the sensor unit is switched off information is not lost. This is important since it enables power to be completely shut down to the main components of pressure sensor in the interval between sensor readings. An example of a suitable memory device is shown in Figure 6.

The microcontroller 15 accepts a signal from each of the pressure transducer 10. the

temperature transducer 11 and the reference voltage generator 12. It processes these signals and provides an output signal to the transmitter 14 which includes the unique sensor identification code for the pressure sensor. An example of a suitable microcontroller is shown in Figure 7. Each time the microcontroller 15 receives a signal from the pressure transducer 10 it also records the battery voltage and temperature. Thus, with the appropriate programming, it is able to determine an accurate pressure measurement for the ~~tyre~~ tire. The ~~tyre~~ tire pressure measurement is compared with a stored (notionally correct) reference value and if the ~~tyre~~ tire pressure is determined to deviate from this by a predetermined amount a message is generated by the microcontroller 15 for transmission. In addition to, or even in the absence of, any message relating to the condition of the ~~tyre~~ tire or driving conditions, the microcontroller 15 is arranged periodically to generate an identification message for transmission which serves to confirm that the pressure sensor remains operational. Failure to transmit such a message will eventually cause a warning to be displayed on the cab unit 1 to indicate to the driver that the pressure sensor has either failed or been removed.

A computer program is embedded within the microcontroller 15 which controls the operation of the pressure sensor. The computer program is executed when power is applied to the microcontroller 15 by the timing circuit 16, initiated by the timer 19. The computer program contains two distinct parts. One part executes during a calibration cycle and the other part executes at all other times. The microcontroller 15 decides which part to execute by examining the state of the MODE input pin (pin 7 in Figure 7). As shown in the pseudocode below and the flow chart of Figure 8, during calibration the MODE pin is initially set to a low state by a calibration jig (not shown). At all other times it is kept in a high state. Once calibration commences the MODE pin is used as a bi-directional path

for signals between the microcontroller 15 and the calibration jig.

```
START of PROGRAM
Carry out system initialising tasks
Read the status of the MODE pin

IF MODE pin is in low state THEN
        Execute Calibrate_Code
ELSE
        Execute Normal_Code
ENDIF
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The pseudocode below and flow chart of Figure 8 detail the calibration procedure for a pressure sensor:

Calibrate_Code

Wait for the MODE pin to signal that the calibration jig has stabilised the pressure at a low reference value. Provide a high excitation voltage to the pressure transducer. via OUTB of the D-A converter of the pressure transducer 10 (Figure 3). Adjust OUTA of the D-A converter to provide zero output between the pressure transducer outputs (OUT+ and OUT-).

Store the digital value required to achieve the zero output in the Non-Volatile Memory (Step XX).

Wait for the MODE pin to signal that the calibration jig has stabilised the pressure at the high reference value.

Adjust OUTA of the D-A converter to provide a standard output between the pressure transducer outputs (OUT+ and OUT-).

Store the digital value required to achieve the standard output in the Non-Volatile Memory (Step YY).

Wait for the MODE pin to signal that the calibration jig has stabilised the pressure at one of several intermediate pressure reference values. For each pressure step:

Using the calibration coefficients stored in Non-Volatile memory (Steps XX and YY above) calculate the expected pressure transducer output: and.

Measure the output of the pressure transducer and compare it with the calculated value.

Set a flag bit in memory to indicate agreement betweeen the measured and calculated values.

The MODE pin is driven by the calibration jig (not shown) which provides manufacturing date code. the identification code for the unit. an initial reference pressure of zero. multi-count value. percentage pressure band limits. battery condition flag and other information that may be required to be stored. This data is routed to and stored in the non-volatile memory.

The pseudo code below and flow chart of Figure 9 details the normal operation of the pressure sensor:

```
Normal_Code
Recover the value of the Reference Pressure from the Non-Volatile Memory.
IF the stored Reference Pressure is zero THEN
        Recover the pressure calibration coefficients from the Non-Volatile Memory.
        Read the temperature transducer to determine the current temperature.
        Read the current pressure and apply temperature corrections.
        If the corrected current pressure is less than a small figure (typically 2 PSI) THEN
                Do nothing
        ELSE
                Write the current pressure into a Reference Pressure location in the Non-
                Volatile Memory.
                Recover the unit identification code from the Non-Volatile Memory.
                Transmit the sensor identification code to the Cab Unit via the transmitter and
                antenna together with a message indicating that this is an initial transmission
                from the particular sensor. Repeat the transmission several times to increase
                the probability of correct reception by the Cab Unit.
        ENDIF
        Disable the Power Switch (Sleep)
ELSE
        Recover the multi-count value from Non-Volatile Memory
        IF the multi-count is not zero THEN
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Recover the current cycle-counter value

IF the value of the cycle-counter is not zero THEN

Decrement the cycle-counter value

Write the cycle-counter value back into Non-Volatile Memory

Disable the Power Switch (Sleep)

ENDIF

ENDIF

ENDIF

Recover the battery low flag from Non-Volatile memory

IF the battery low flag indicates a healthy battery THEN

Write the multi-count value into Non-Volatile Memory to initialise a new count down sequence.

ELSE

Write an increased multi-count value into Non-Volatile Memory to initialise a new larger (battery conserving) count down cycle.

ENDIF

Recover the calibration coefficients from the Non-Volatile Memory.

Send the calibration coefficients to the D-A converter where they will be converted to voltages at OUTA and OUTB.

Read the temperature transducer to ascertain the current temperature.

Set the temperature warning flag if the temperature is low enough to merit warning the driver that road conditions are becoming hazardous.

Read the current output from the pressure transducer circuit and apply temperature

corrections.

Recover the acceptable percentage band limits from the Non-Volatile Memory.

Compare the reference pressure with the pressure reading that has just been taken and corrected for temperature effects.

IF pressure is outside acceptable percentage limits THEN

Set a flag Pressure Warning flag

ENDIF

Determine the battery voltage using the voltage reference and potential divider.

Determine if the voltage is above a threshold that indicates a healthy battery.

IF the battery voltage check indicates that the battery is beginning to fail THEN

Set a battery-low flag into Non Volatile Memory.

ENDIF

Compose a message containing the sensor identification code. the result of the pressure check. the temperature flag and the battery condition.

Transmit the message to the Cab Unit via the transmitter and antenna together with a header indicating that this is a routine transmission.

IF the pressure reading was outside the acceptable percentage band limits THEN

Repeat the transmission several times to increase the probability of reception.

IF the pressure reading was zero THEN

Set the reference pressure stored in the Non-Volatile Memory to zero.

ENDIF

ENDIF

Disable the Power Switch (Sleep)

Figure 10 shows a schematic representation of an example of a cab unit 1 suitable for use in the tyre pressure monitoring system. The cab unit 1 comprises a receiving antenna 30, a microcontroller 31, a driver's display 32 to display information about the tyres to the driver, and a memory 33. The microcontroller 31 is able to distinguish between signals and identify, by way of its unique identification code, which pressure sensor or transponder unit is sending each signal. In normal operation, each pressure sensor periodically transmits an "all's-well" signal. If the cab unit 1 detects two consecutive missing signals from the same unit, an LED will flash to tell the driver to check that ~~tyre~~ tire. The cab unit 1 can display warnings whenever any ~~tyre~~ tire is suffering from any of low pressure, low temperature, low battery or a missing sensor unit. The drivers cab display 32 is shown in detail in Figure 11.

The drivers cab display 32 has the following items:

- a two digit wheel number indicator 40 with two small adjacent LED indicators. One LED illuminates when the wheel number displayed relates to the cab and the other illuminates when the wheel number relates to a trailer;
- further LEDs 41 to 44 provide "low temperature", "low pressure", "low battery", and "unit missing" warnings, respectively; and,
- a switch 45 with positions, LEARN CAB, LEARN TRAILER and NORMAL, with small LEDs to indicate a teaching process (to be described below) is being carried out.

An acoustic sounder (not shown) is included in the cab unit 1 and sounds for ten seconds

after a warning message is received and every five minutes thereafter. When the ignition is turned on the sounder makes a short chirp. If a warning message has been received during driver absence it will sound for ten seconds. Power is supplied continuously by the vehicle battery or via the ignition circuit. A "cancel" button (not shown) is also provided which can disable a warning entry until the next ignition off-on cycle.

Figure 12 shows a schematic representation of an example of a transponder unit 3 for a trailer. The transponder unit comprises a receiver 51. a microcontroller 52 and a transmitter 53. The receiver 51 periodically receives signals transmitted by individual tire ~~tyre~~ pressure sensors and couples the signals to the microcontroller 52. The microcontroller 52 processes a signal and generates a new message which incorporates a unique identification code associated with the transponder unit 3 as a header which is transmitted by the transmitter 53 and which can be detected by the cab unit. This identification code. as with the pressure sensors. is stored in a memory 54.

Referring to Figure 11 above. when fitting pressure sensors to a single vehicle or a cab. the driver selects the LEARN feature to indicate that pressure sensors are about to be installed on the wheels. The cab unit 1 then wipes out all stored information (if any) relating to previous wheels. The driver then walks around the vehicle fitting pressure sensors to each of the valves of the wheels in a predetermined order. Once fitted. a pressure sensor recognises it has lifted off from 0 psi and sends its identification code several times. After each pressure sensor is fitted the driver must wait for the cab unit 1 to sound to indicate that it has recognised the new sensor unit successfully before proceeding to the next wheel. After all the wheels have been fitted with a pressure sensor. the driver then selects the

NORMAL feature. At this stage the cab unit 1 now knows how many wheels are present and their identification codes. and the monitoring system is then ready for use.

When fitting pressure sensors to a trailer. the driver selects a corresponding LEARN TRAILER feature on the trailer transponder unit 3 (not shown). The driver then walks around the trailer in the same manner as for a cab unit. fitting each of the wheels in turn with a pressure sensor so that the trailer transponder unit 3 knows how many wheels are present and their identification codes. When the trailer is then connected to the vehicle cab. the driver selects the LEARN TRAILER feature on the cab unit 1 so that any previous information relating to trailers is deleted. After the ignition is turned on. when the brake pedal is first depressed the trailer transponder unit 3 recognises that it should identify itself to the cab unit 1 because this is the first time it has had power supplied and the brake light line is active. It then transmits its unique identification code to the cab unit 1 to identify itself as a new trailer. This identification code for the trailer is then stored in the cab unit 1. The driver subsequently selects the NORMAL feature and the system is now ready for use.

As an alternative. the "learn trailer" step can be automated so that the driver does not even need to select this on the cab unit - the registration process is carried out automatically after ignition is switched on.

The cab unit 1 receives transmissions from the cab's wheels. which are recognised. and trailer wheel messages which are ignored. The trailer transponder unit 3 receives transmission from its own wheels. which are recognised. and the cab wheels which are

ignored. As described above, information from the trailer wheels is stored in the trailer transponder unit 3 and warning and other messages from the trailer transponder unit 3 are relayed to the cab with a message header so that they are recognised by the cab. It is proposed that warning messages are passed to the cab immediately by the transponder unit 3 whereas routine "all's well" messages are only sent periodically.

It is possible to build on the tire ~~tyre~~ pressure monitoring system of the present invention to provide a complete tire ~~tyre~~ management system for a fleet operator. The idea is that as each vehicle returns to a depot, the cab unit is automatically interrogated to determine the condition of each tire ~~tyre~~. The vehicle depot keeps a computer database which provides a record of the vehicle movements and a list of which tires ~~tyres~~ on which vehicles need attention. In this way, the need to rely on driver trip reports is reduced. The depot system could also be programmed to interrogate vehicles as they leave a depot as a double check that any defective tires ~~tyres~~ have been duly corrected.